FACTORS AFFECTING THE PRODUCTION AND REPRODUCTION PERFORMANCE OF TROPICALLY ADAPTED BEEF CATTLE IN SOUTHERN AFRICA

by

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SUMMARY

In the first study, non-genetic influences on pre- and post-weaning growth traits of a tropically adapted beef breed in the arid sub-tropical environment of Southern Africa were investigated. Production data of Santa Gertrudis cattle for a ten-year period were analysed. The herds were managed extensively under harsh arid environmental conditions in the northern thornveld region of Namibia. The cattle were divided into summer and winter breeding seasons, which were limited to 90 days for each group. The effect of sex, herd, season, calf birth year and cow parity group on birth weight, pre-weaning average daily gain, weaning weight, yearling weight, eighteen month weight and post-weaning growth rate were analysed. Sex was a highly significant ($p < 0.001$) source of variation for birth weight, weaning weight, 12 month weight, 18 month weight and significantly influenced ($p < 0.05$) pre and post-weaning weight gain. Bull calves were 3.05, 13.75, 123.37 and 238.99 kg heavier than the heifer calves at birth, weaning, yearling and eighteen months respectively and grew faster by 0.07 kg/day from birth to weaning and 0.65 kg/day from weaning to 12 months of age. The effect of season on birth weight, weaning weight, 18-month weight and pre-weaning growth rate was highly significant ($p < 0.001$). Calves born in the summer season had a lower birth weight compared to calves born in the winter season. However, the summer season calves were heavier by 17.67 kg at weaning but only by 1.7 kg at 12 months of age. They grew faster by 0.16 kg/day from birth to weaning. Calf birth year significantly influenced ($p < 0.001$) all traits measured with no fixed trend over time for the traits. Herd effects were highly significant ($p < 0.001$) for birth weight and 12-month weights and significantly influenced ($p < 0.05$) weaning weight, 18-month weight and growth rate from weaning to 12 months of age. The effect of cow parity was not significant on birth weight, 12-month weights, 18-month weights and post-weaning growth rates, but was significant ($p < 0.05$) for weaning weight and pre-weaning growth rates. Sex, herd, season of calving, calf birth year and herd x season x calf birth year significantly influenced growth traits and should be taken into consideration when evaluating the genetic merit of cattle during selection.

The second study was conducted to determine the associations between lifetime cow fertility and cow frame size, also between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle. A total of 2 506 Santa Gertrudis cows were divided according to their average lifetime calving interval (CI) into short calving interval (SCI, < 400 days, n = 914 cows) and long calving interval (LCI, > 400 days, n = 1 592 cows) groups. Calves were weighed at weaning at approximately 7 months of age. Hip height of cows and pre-weaning gain of calves of the SCI cows (135 cm and 1.01 kg/day) were significantly ($p < 0.05$) lower than those of the LCI cows (141 cm and 1.25 kg/day). Calves from SCI cows were born significantly earlier in the calving season than calves from LCI cows as measured by age at weaning (221 versus 189 days). As a result of compensatory growth there was no significant difference for yearling weight between progeny of SCI and LCI cows (348 kg versus 349 kg). It is concluded that SCI cows are smaller in size, with significantly lighter calves at weaning. A negative correlation exists between fertility and pre-weaning calf growth. High post-weaning calf growth is compatible with high cow fertility.

In the third study, the effects of heifer frame size (FS) on their subsequent performance and the pre-weaning growth of their calves were evaluated using records collected from 1989 to 1998 from the Waterburg Estates at Otjiwarongo, Namibia. Based on hip height at 18 months of age, heifers were assigned to three different frame size (FS) groups: small (< 124 cm), medium (125 to 135 cm), or large (>136 cm). Calving rate (CR), calving date (CD), calf survival rate (CSR), reproductive efficiency (SANDEX), weaning rate (WR), birth weight (BW), weaning weight (WWT), pre-weaning ADG (P-ADG), and kilograms of calf produced per cow bred (KCB) were collected from first –(n = 830), second (n = 623) and third and greater-parity (n = 571) cows. Frame size of heifers significantly influenced ($p < 0.001$) their calving rate as second-parity cows with small and medium FS cows having higher CR than large FS cows. In spite of heavy culling of cows that had large FS as heifers, calving rates of second parity cows in this category were 41% less than that of second parity cows that had small and medium FS as heifers. In third or greater-parity cows, CR was greater ($p < 0.05$) for small FS than for medium and large FS. CSR was similar for heifers with a small, medium and large FS for the first, second and third and greater parity groups. Weaning rates of large FS (34.2 ± 11.27), second-parity cows were less ($p < 0.001$) than those of small (82.9 ± 5.58) and medium (79.0 ± 4.67) FS animals. Among all parity groups, BW of calves born to large FS were significantly higher ($p < 0.05$) than those of small and medium FS cows. Calves weaned by small FS animals as first parity cows, had lower ($p < 0.05$) WWT than those weaned by medium and larger FS, but large FS weaned heavier calves ($p < 0.05$) than small and medium FS in the third and greater-parity group. In first parity cows, calves of large FS had greater P-ADG ($p < 0.05$) than those from small FS, but in second parity cows the calves from medium FS ($p < 0.05$) out performed those of small and large FS, while calves from third and greater parity cows of medium and larger FS had greater ($p < 0.05$) P-ADG than cows with a small FS. Male calves were heavier ($p < 0.05$) at birth, at weaning and grew faster (P-ADG) than their female counterparts. KCB was similar among small and medium FS cows, but both tended to be greater ($p < 0.05$) than KCB of large FS cows and as second parity cows the small and medium FS cows had an even greater ($p < 0.001$) advantage over the large FS animals. Small and medium FS females calved earlier, and had greater calving rates and weaning rates, as well as greater kilogram of calf produced per cow exposed than the large FS females. The performance (fertility and the growth performance of their calves to weaning) traits of the large FS were generally similar to those of smaller cows in the third and greater parity group. The reproductive efficiency (SANDEX) of large FS at first, second, third and greater parity were lower ($p < 0.001$) compared to the small and medium FS, due to the later calving dates. Therefore, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a medium frame. These animals have similar levels of fertility

compared to small framed cows, but with similar or even better growth performances than large framed cows.

In the fourth study, the objective was to determine the effect of traits such as age, sex, body weight, body length and height, body condition score (BCS), coat score (CS), skin thickness and average skin surface temperature on tick burdens of a tropically adapted beef breed. Bonsmara cattle (n= 143) were used to measure visible tick counts, body condition score, coat score, skin thickness, body height and length, body weight, body surface temperature, gender and inter calving period. Measurements were taken for a period of eight months from April to December. All animals were managed extensively on natural and cultivated pastures near George in the Southern Cape. Female animals had significantly ($p<0.05$) greater tick infestation (37.9±2.7) compared to male animals (16.5±1.2). Age was a significant factor ($p<0.001$) with the younger animals below two years having (46.4±5.26) more ticks than those of two years and older (20.1±2.44). A significant negative correlation ($r = -0.29$; $p<0.001$) was reported between the infestation of ticks on the animals and the age of the animal. Animals with an average body weight below 250kg had 42% ($p<0.05$) more ticks compared to animals with a body weight above 250kg. Age of the animal and weight were highly correlated ($r = 0.70$; $p<0.001$), while the correlation between the number of ticks per cow and the mean weight was negatively correlated ($r = -0.37$; $p<0.001$). Skin surface temperature significantly influenced tick infestation on the animals ($p<0.001$). The degree of infestation increased as body surface temperature exceeded 30º Celsius. Coat score, skin thickness, body condition score and inter calving period did not significantly influence tick infestation on the animals. The infestation of ticks on the animals was significantly influenced by body height ($p<0.019$) and body length ($p<0.001$). Animals smaller than a 130cm in height had a significantly ($p<0.05$) greater tick infestation (36.5±5.0) compared to animals taller than 130cm (21.2±1.5). This trend was also observed for body length. Animals with a body length shorter than 145cm had a greater ($p<0.05$) average tick infestation of 41.3±4.5 compared to 23.2±1.3 for animals longer than 145cm, indicating a 44% greater tick infestation for the shorter animals. The selection of cattle for adaptability and thus increased production under tropical conditions, through resistance to ticks should be for animals of medium frame sizes having smoother coats that are able to dissipate heat effectively.

In the fifth study, the relationship between growth parameters, scrotal circumference and sheath area in tropically adapted beef bulls was investigated. The relationship between growth parameters such as initial weight at the start of the trial, average daily gain for the trial period (ADG), average daily gain per day of age (ADA), feed conversion ratio (FCR), final weight at the end of the trial, scrotal circumference (SC) and age and sheath area in Santa Gertrudis bulls were examined. To investigate the relationship between growth parameters and scrotal circumference, growth test data of 97 on-station performance tested Santa Gertrudis bulls were used while growth results of 55 Santa Gertrudis bulls tested under semi-intensive conditions were used to investigate the relationship of sheath area with growth performance. Bulls were divided into two groups according to their average sheath area (470 cm^2). 28 Bulls were assigned to the small sheath group (SSA) below 470 cm^2 while 27 bulls were assigned to the large sheath group

(LSA) above 470 cm^2. The LSA group possessed a 15% (66 kg; $p < 0.05$) heavier final weight than that of the SSA group. The LSA group had a 64% (241 cm^2; $p < 0.05$) larger sheath area (378 ± 60 vs 619 ± 161 cm^2) than the SSA group. A significant phenotypic correlation between ADG ($r = 0.31$, $p < 0.05$) and sheath area was found. The correlations between sheath area and initial weight ($r = 0.42$, $p < 0.001$) and between sheath area and final weight ($r = 0.45$, $p < 0.001$) were also highly significant. A highly significant correlation ($p < 0.001$) was observed between initial weight and SC and between final weight and SC, while significant correlations ($p < 0.05$) were also observed between SC and age and between SC and ADA for bulls tested intensively on station. It appears that SC and faster growth rate are compatible in young bulls. In addition, giving careful attention to sheath area in bulls, selected as yearlings is possible without necessarily sacrificing growth performance.

In the sixth study, associations among growth and quantitative testicular traits of tropically adapted yearling bulls fed different dietary energy levels were investigated. High energy (HE), medium energy (ME) and low energy (LE) diets were fed to young Bonsmara bulls post-weaning and the subsequent effects on scrotal circumference (SC), average daily gain over an 84 day performance test trial period (ADG), average daily gain per day of age (ADA), body condition score (BCS), testicular histology and seminal traits were examined. Bulls fed the HE diet were significantly heavier and had a greater ADA, with the HE bulls (999.1 ± 7.13 g) out-performing the ME (804.1 ± 12.61 g) and LE (713.2 ± 12.95 g) bulls in terms of growth rate over the duration of the experimental period. Diet influenced ($p < 0.001$) BCS with the HE bulls (3.9 ± 0.05) having more body fat compared to the ME (3.3 ± 0.06) and LE (3.0 ± 0.08) bulls with the same effect ($p < 0.001$) observed in the carcass dressing percentage of the bulls fed different levels of energy. SC did not differ significantly between HE, ME and LE fed bulls. Seminal traits, such as semen concentration were significantly ($p < 0.001$) lower in bulls fed the HE diet (1.3 ± 0.134) compared to those fed the ME diet (2.4 ± 0.18) and LE diet (2.6 ± 0.16). Similarly, linear movement of sperm was also affected by diet and movement was slower ($p < 0.05$) in bulls fed the HE diet (1.7 ± 0.30) compared to bulls fed the ME diet (2.2 ± 0.31) and LE diet (3.1 ± 0.23). The percentage total major ($p < 0.001$) and total minor ($p < 0.05$) sperm defects were also greater in the HE fed bulls (27.1 ± 6.82 and 7.4 ± 0.91% compared to 9.7 ± 1.45 and 5.5 ± 0.87% for the ME fed bulls and 5.4 ± 1.26 and 3.9 ± 6.58% for the LE fed bulls). Dietary energy level significantly ($p < 0.001$) influenced the percentage inactive seminiferous tubuli, with bulls fed the HE diet having 35% more seminiferous tubules classified as inactive compared to those bulls fed ME and LE diets. Scrotal fat deposits were higher ($p < 0.05$) in bulls fed the HE diet (243.4 ± 21.59 g) compared to those fed the ME (110.0 ± 12.1 g) and LE (88.4 ± 9.65 g) diets. Correlation coefficients between SC and growth traits were generally favourable for the different dietary treatments. Correlations between live weight and SC were 0.51, 0.45 and 0.52 ($p < 0.05$) for the HE, ME and LE groups respectively. A negative association was observed between BCS and progressive sperm motility in bulls fed the HE diet ($r = -0.54$, $p < 0.05$). The percentage major seminal defects was negatively correlated with live weight in bulls fed the LE diet ($r = -0.46$, $p = 0.008$) and ME diet ($r = -0.40$, $p = 0.08$), while this characteristic was negatively correlated with mass movement of sperm ($r = -0.63$; $p < 0.05$) and percentage live sperm ($r = -0.60$; $p < 0.05$) in HE fed bulls. The present results suggest that feeding HE diets to young bulls influenced their testicular development and reduced their reproductive potential.

In the seventh and last study, the relationship between scrotal circumference, quantitative testicular traits and growth performance in tropically adapted yearling beef bulls differing in age was investigated. The bulls were fed a high energy diet and the effect on average daily gain (ADG), average daily gain per day of age (ADA), body condition score (BCS), feed conversion efficiency (FCE), scrotal circumference (SC), seminal traits and testicular histology were examined in Bonsmara bulls (n = 34). The high energy diet contained not less than 11 MJ ME / kg DM and 13.8% CP. Bulls were fed the HE diet from an average starting age of either 210 (YB; n = 17) or 257 days (OB; n = 17) for a total of 112 days. Despite the age difference, growth and carcass traits were similar for the bulls irrespective of starting age. Scrotal weight, scrotal skin weight and scrotal skin thickness were greater ($p < 0.001$) in the YB (2223.4 ± 11.68g; 576.6 ± 25.17g and 4.5 ± 0.15mm) compared to that of the older group (1010.15 ± 50.10g; 255.9 ± 13.55g and 4.0 ± 0.13mm). The weight of the epididymal / spermatic cord (WESC) was heavier ($p < 0.05$) in the older bulls (70.2 ± 3.53g) compared to that of the younger group (47.2 ± 3.17g) with a similar trend observed when the volume of the epididymal / spermatic cord (VESC) was measured. Scrotal fat deposition was significantly ($p < 0.001$) increased by initial age (YB = 1164.7 ± 102.20g vs OB = 263.5 ± 27.52g). Age of the bulls also influenced ($p < 0.05$) the percentage inactive seminiferous tubuli, with the young bulls having 9.7% more seminiferous tubules classified as inactive compared to the older bulls. Seminal quality showed a similar trend and was generally of a lower standard than that of the group tested at an average of 369 days of age. Semen concentration ($p < 0.05$) and percentage linear sperm motility ($p < 0.08$) were the traits most affected by age. A negative correlation was evident between BCS and testis weight ($r = -0.51$; $p = 0.0342$), testis volume ($r = -0.52$; $p = 0.0318$) and SC of dissected testis ($r = -0.49$; $p = 0.042$) in the young bulls. Correlation coefficients between SC and testis traits such as testis weight and testis volume were high ($p < 0.05$) for both the groups (YB; $r = 0.87$ and $r = 0.87$ and OB; $r = 0.77$ and $r = 0.81$). The relationship between SC and scrotal fat ($r = 0.85$) was highly significant ($p < 0.001$) only in the younger group. The results suggest that when bulls are fed a high energy diet, the age at which such feeding commences is of importance as regards their subsequent fertility.

PREFACE

The purpose of this study was to critically evaluate factors that influence the production and reproduction of beef cattle, managed extensively on natural pasture in the sub-tropical region of Southern Africa. Significant progress was made and valuable information obtained in the fields of beef cattle production science over the past 50 years. Despite moving from subjective measuring methods to more scientific, objective means of measurement, very little progress has been made in terms of the national calving percentage over the past 30 years. Hopefully the study has made a meaningful contribution to emphasize factors which effect production and reproductive performance of beef cattle managed extensively on natural pasture and in the process challenge existing practises.

The thesis is divided into three sections: Section A includes a general introduction and three articles that deal with factors affecting production and reproduction in the cow herd, with the focus being on the effect of heifer size and the subsequent productivity of their progeny and on herd productivity. Section B focuses on traits that determine the parasite load in tropically adapted cattle. Section C focuses on factors affecting the fertility and production in bulls. It is attempted through the three sections to contribute significantly to the existing information of beef production science in a scientific and coherent fashion. Due to the structure of the thesis and nature of the study a limited amount of repetition was unavoidable. However, every effort has been made to limit repetition.

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I hereby declare that this thesis submitted for the degree of Doctor of Philosophy is my original work and has not been submitted by me in respect of a degree to any other University, and the views expressed are my own.

G. J. TAYLOR

LIST OF ABBREVIATIONS

AAS	Age at slaughter
ADG	Average daily gain
ADA	Average daily gain per day of age
BSE	Breeding soundness examination
BS temp	Body surface temperature
BW	Birth weight
CD	Calving date
CDP	Carcass dressing percentage
CFG	Carcass fat grade
CI	Calving interval
CLT	Circumference of left testis
cm	Centimetre
cm^3	Cubic Centimetre
CR	Calving rate
CRT	Circumference of right testis
CS	Coat score
CSR	Calf survival rate
DM	Dry matter
ESC	Epididymis and spermatic cord
ESR	Epididymal sperm reserves
FCE	Feed conversion efficiency
FCR	Feed conversion ratio
FS	Frame size

g	Grams
ha	Hectares
HE	High energy
HFG	High fertility group
ICP	Inter calving period
Kg	Kilogram
LCI	Long calving interval
LE	Low energy
LFG	Low fertility group
LSA	Large sheath area
LSG	Large sheath group
LSU	Large stock unit
LW	Live weight
max	Maximum
ME	Medium energy
MFG	Medium fertility group
mg	Milligrams
min	Minimum
MJ	Mega joules
mm	Millimetres
n	number
OB	Older bull group
P-ADG	Pre-weaning average daily gain
PEC	Production efficiency per group
PEG	Production efficiency per cow group

PIT	Percentage inactive tubuli
PLS	Percentage live sperm
PLSM	Percentage linear sperm motility
PMSD	Percentage major sperm defects
PMISD	Percentage minor sperm defects
PPG	Kilograms of calf produced per cow bred
PTW	Paired testis weight
R	Rands
SCI	Short calving interval
SC	Scrotal circumference
Scon	Sperm concentration
Scount	Sperm count
SEM	Standard error of the mean
SF	Scrotal fat
SMM	Sperm mass movement
SSA	Small sheath area
SSG	Small sheath group
SST	Scrotal skin thickness
SSW	Scrotal skin weight
SW	Scrotal weight
TTV	Total testicular circumference
VESC	Volume of the epididymal spermatic cord
VS	Versus
YB	Young bull group
WCC	Weight of cold carcass

WCW	Weight of warm carcass
WESC	Weight of the epididymal spermatic cord
WLT	Weight of left testis
WR	Weaning rate
WRT	Weight of right testis
WWT	Weaning weight

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